# The Mars 2020 Rock Hazard Pipeline

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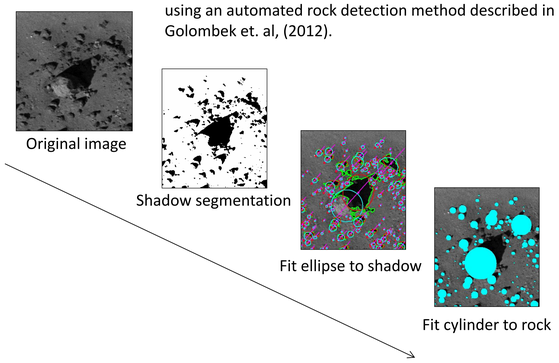
## Overview

The Mars 2020 mission will send a ~950kg curiosity class rover to conduct in-situ science, and collect samples for potential future return to Earth. Rocks are a significant hazard that must be considered in landing site selection, as they can tip or damage a rover during landing, and limit traversability after landing. **We designed a workflow for the characterization of rock hazards at candidate landing sites .**


## Detection

Non-georeferenced Image → Rock Detection → Detected Rocks (Text File) → Convert to Polygons → Detected Rocks (Shapefile)

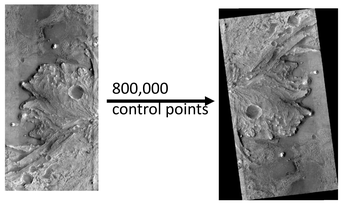
Rocks are resolved from ~30cm/pixel satellite imagery using an automated rock detection method described in Golombek et. al, (2012).




## Georeferencing

Orthorectified Image → Image Registration → Tie Points (Text File) → Spline Transformation

Shapefiles of detected rocks are warped using ~ 800,000 control points between the detection image and an orthorectified basemap.

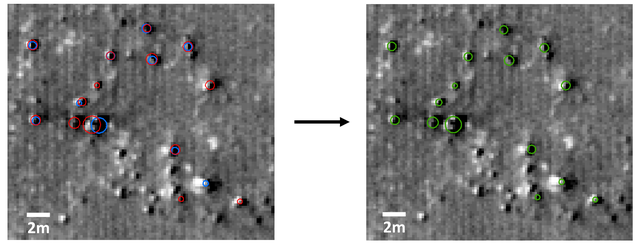



For Each Image → Georeferenced rocks

## Merging

Rock Merging → Merged Rocks

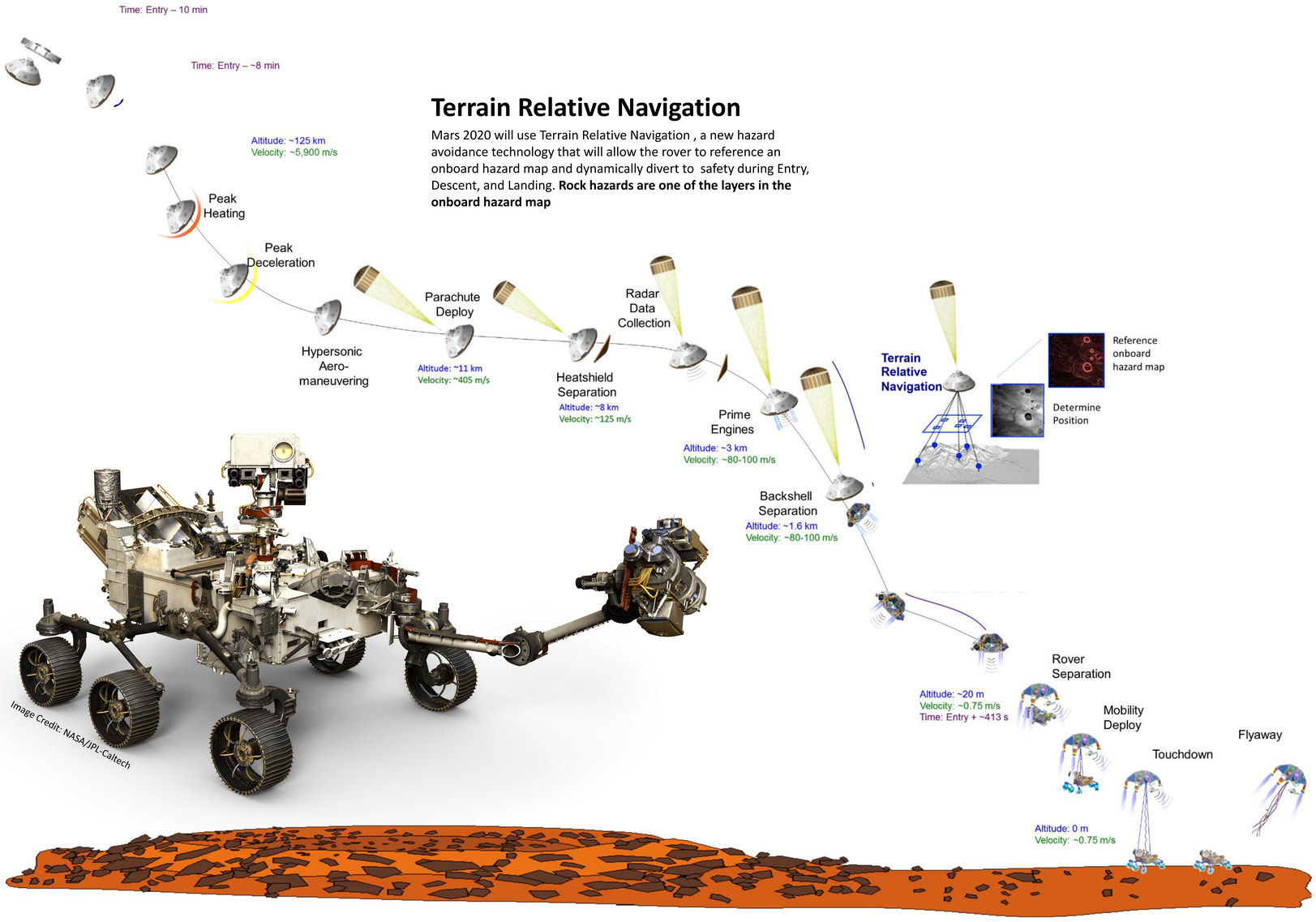
Now that the shapefiles of detected rocks are georeferenced and in a common data frame, they are combined. In overlapping regions, duplicate rock detections are identified and replaced with a new rock that is of the average position and diameter of the detections.




Remove Duplicate Detections

## Terrain Relative Navigation

Mars 2020 will use Terrain Relative Navigation , a new hazard avoidance technology that will allow the rover to reference an onboard hazard map and dynamically divert to safety during Entry, Descent, and Landing. **Rock hazards are one of the layers in the onboard hazard map**

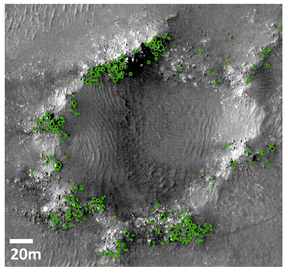



## Model Fitting

Rock Model Fitting ← Rock Model

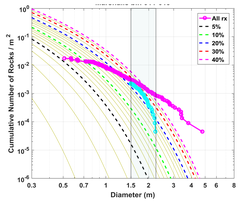
Rock Hazard

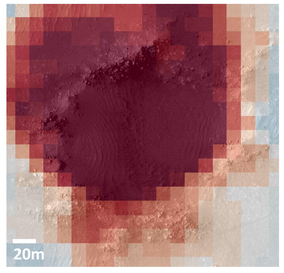
Rock abundance is calculated by Cumulative Fractional Area models to detected rock populations




$$F_k(D) = ke^{-q(k)D}$$
$$q(k) = 1.79 + \frac{0.152}{k}$$

Solve for $k$




## References

Golombek, M. P., Huertas, A., Marlow, J., McGrane, B., Klein, C., Martinez, M., … Cheng, Y. (2009). Size-frequency distributions of rocks on the northern plains of Mars with special reference to Phoenix landing surfaces. Journal of Geophysical Research E: Planets, 114(3), 1–32.

Golombek, M., Huertas, A., Kipp, D., and Calef, F. (2012). Detection and Characterization of Rocks and Rock Size-Frequency Distributions at the Final Four Mars Science Laboratory Landing Sites. *Mars*, *7*, 1–22.

Chen, A., Hines, E., Otero, R., Stehura, A., and Villar, G. (2014). Mars 2020 Entry, Descent, and Landing System Overview. Pasadena, CA: 11th International Planetary Probe Workshop.